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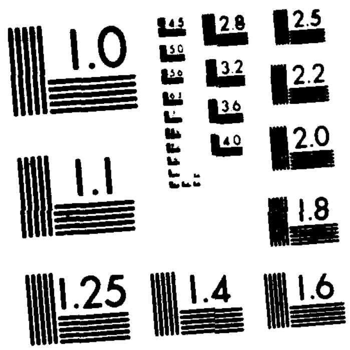

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USAARL Report No. 87-9

Direct Determination of the Adequacy of Hearing Protection for Use with the VIPER

James H. Patterson, Jr.
Ben T. Mozo

Sensory Research Division

August 1987

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USAARL

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During developmental testing it was determined that the VIPER antitank weapon produced impulse noise which exceeded the maximum levels permitted by MIL-STD-1474. In order to proceed with operational tests, it was necessary to determine whether adequate hearing protection could be provided. This study involved the exposure of 38 volunteers to two rounds of VIPER fired in rapid succession while wearing EAR(TM) earplugs. The average exposure peak level was 181 dB SPL. Audiograms were taken before and after exposure. No detectable changes in hearing were observed in the group of volunteers. From this, it was

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concluded that EAR™ earplugs provide adequate protection for at least two rounds of VIPER.

Acknowledgment

The authors express their appreciation for the assistance of Mr. Ron Marrow, SGT Ilia Lomba and Mr. Ted Moritz during data collection and to Ms. Linda Barlow for assistance in data analysis and preparation of figures. We also appreciate the assistance of COL Ed Buescher and LTC J.D. LaMothe, Headquarters, U.S. Army Medical Research and Development Command, for their coordination efforts; members of the Project Managers Office, VIPER, especially COL C.M. Matthews, COL A.J. Larkins, Mr. Joe Mitchell and CPT D.M. Prescott for supporting the project; Mr. John Chipser, Human Engineering Laboratory (HEL) Detachment, Missile Command, for blast data collection and analysis at Redstone Arsenal, Huntsville, AL; members of the U.S. Army Infantry Board, especially MAJ Wells for local support at Fort Benning, GA; and Dr. Dave Hodge and Mr. George Garinther, HEL, Aberdeen Proving Ground, MD, for assistance with volunteers at Fort Benning, GA.

Table of contents

List of figures

List of tables

Introduction

MIL-STD-1474A(MI)* specifies limits on the noise which an Army weapon system can produce. For impulse noise, these limits are a family of curves which define a relationship between peak pressure and B-duration. The highest of these, the "Z-curve," defines the maximum impulse noise permitted. The VIPER, a developmental shoulder-fired antitank weapon, produced impulse noise levels that exceeded the Z-curve of MIL-STD-1474, even after extensive engineering attempts to reduce the noise levels.

The Office of The Surgeon General of the Army recommended that exposure of soldiers to impulse noise at these levels not be permitted without direct evidence that adequate hearing protection could be provided. In order to conduct operational testing with the VIPER, the Project Manager for VIPER requested assistance to verify that adequate hearing protection was available. From August to December 1980, the US Army Medical Research and Development Command (USAMRDC) assisted the Project Manager for VIPER in conducting a study to determine directly the adequacy of hearing protection for the impulse noise produced by this system.

The basis for this study rests in the nature of the auditory system's response to intense noise. It has been known for years that high intensity noise will cause alterations in the hearing of individuals who are exposed to this noise. With relatively mild exposures, the effect on hearing is an elevation of the auditory threshold which is transitory; that is, the exposure is elevated above normal levels for a short time. In a matter of minutes, hours, or days, the threshold will recover and return to the pre-threshold levels. This phenomenon is known as temporary threshold shift (TTS).

Generally, it is believed that sounds which produce small TTSs which recover rapidly are not producing any significant permanent hearing losses (Henderson et al., 1976). There is ample evidence in the literature to demonstrate that small TTSs (less than 35 dB) can be induced occasionally without any long-term (permanent) elevation of the subject's threshold (e.g., Ward, Selters, and Glorig, 1961; Ward, 1962; Hodge and McCommon, 1966). With more severe exposure, again there is an elevation of the threshold, followed by some improvement over a period of days or weeks; however, the return to normal threshold may not occur. In this case, the difference between the preexposure threshold and the threshold after days of recovery is termed a permanent threshold shift. Permanent threshold shift is indicative of an irreversible change in the auditory system and is fundamentally the type of change that we would like to prevent in military personnel.

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*MIL-STD-1474B(MI) is the current edition of this standard. However, the "A" edition was applicable at the time of this work.

The temporary threshold shift that may be a precursor to a permanent injury gives us a possible early warning that an effect on the ear has occurred and, if the exposure becomes much worse, then the effect can become permanent and irreversible. It is this possibility that allows us to design a study in which we can expose human volunteers to a given noise situation, look for the temporary changes in hearing and, at a point where they still are reversible, gauge the hazard potential for the exposure the volunteers have received.

Methods and instrumentation

Implementation of studies of this type requires instrumentation of laboratory quality in the field to perform two basic tasks. One is to monitor exactly what the volunteers are exposed to at each stage of the study. This requires blast measurement equipment which is field transportable and can measure the blast at or near the position of the subject throughout the course of the experiment. Figure 1 shows the mobile unit that belongs to the US Army Aeromedical Research Laboratory (USAARL) and has been developed for exactly this purpose. Inside the truck is a complement of laboratory quality equipment for monitoring and analyzing blast waves. The beginning of the system is an ST-2 pressure transducer, which is capable of measuring pressures in the range of 170 to 190 decibels (dB). This gauge, or a set of these gauges, is cabled back into the van and fed through a set of calibrated gain amplifiers, and from there into a multichannel data acquisition system, which includes 11 parallel A/D converters, each capable of sampling the pressure-time history at 250,000 samples per second. This provides an accurate digital representation of the blast waves for up to 11 channels simultaneously. In this study, only four channels were used. These waves are stored on a special high bit rate recorder and analyzed off-line by a PDP 11 computer system.

The second task required is audiometric monitoring of volunteers on-site, accomplished by a mobile audiometric facility housed in a 44-foot moving van (Figure 2). This facility permits us to take to the field conditions which are comparable to audiometric facilities in the laboratory.

Study design

This study was designed in two phases. In the first phase, a small number of individuals were exposed to a series of exposures starting with one which was not expected to produce any effect on hearing and proceeding to more severe exposures until the maximum operationally necessary exposure was reached or until TTSs were large enough to indicate further increases would pose the risk of permanent changes in hearing. The second phase was intended to increase the sample size for statistical purposes. The exposure conditions in phase II depended on the outcome of phase I. If no effects on hearing were noted during phase I, then phase II

Figure 1. Instrumentation van for measurement of blast overpressures.

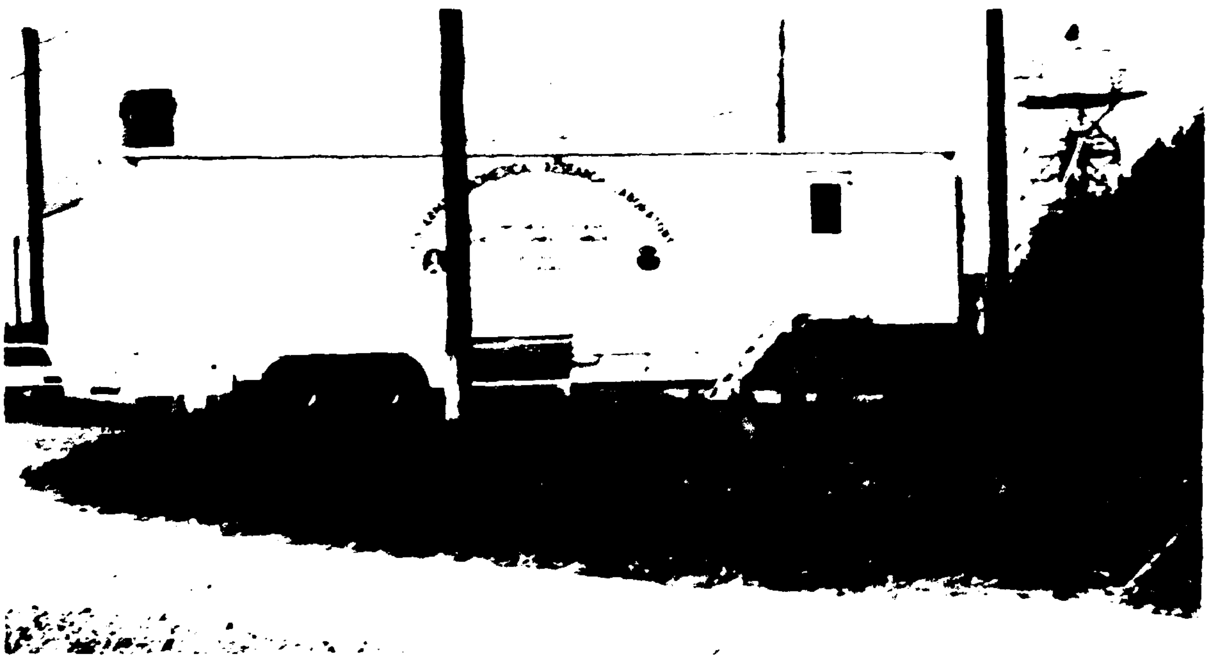

Figure 2. Field audiometry trailer on the range.

would use only the maximum exposure. If effects on hearing were noted in phase I, then phase II would use the same increasing exposure conditions employed in phase I.

Exposure procedures

Prior to any exposures, the noise levels at the gunner's ear position were determined with the VIPER mounted on a test stand. Two positions to the left of the line of fire were identified--one at which the level would be 10 dB below and the other at a level 5 dB below that at the gunner's head position.

During phase I the exposures were given one per day except for the last exposure. Each volunteer was exposed first to one round each at the -10 dB location then at the -5 dB location, each firing being triggered remotely. Then he fired one round holding the weapon and finally fired two rounds as rapidly as possible. Figure 3 shows three volunteers at each of the exposure locations. During phase II, each volunteer was exposed to only two rounds on one day. Figure 4 shows a volunteer in firing position during phase II.

During all exposures the volunteers wore EAR™ brand foam earplugs. These were inserted by the individual and checked by the investigators by visual inspection.

During phase I, all exposures were monitored by personnel from the U.S. Army Missile Command (MICOM) and the MICOM Human Engineering Laboratory (HEL) detachment. Figure 5 shows the gauge locations near each volunteer.

Threshold shift audiometry

Audiograms used for estimating threshold shift were determined on the firing range using a multichannel microprocessor audiometer developed specifically for this study and capable of obtaining audiograms on four subjects simultaneously. Details of this audiometer were described by Mozo, et al., 1984. Briefly, it uses a fixed frequency tracking procedure to determine thresholds. The order of testing various frequencies was 2.0, 4.0, 6.0, 3.0, 8.0, 2.0, 1.0, and .5 kHz. Since 2.0 kHz was tested twice, the first test of this frequency was used as a "warm-up" test and not included in the data analysis. The remaining frequencies were ordered on the basis of likelihood to show an effect.

This audiometer was housed in the USAARL mobile audiometric facility which had been parked approximately 80 meters from the firing point. The trailer has four individual double-walled test booths inside a large single-walled noise excluding room. Additional noise control during audiometric testing was accomplished by use of noise excluding headsets which are part of the audiometer.

Figure 3. [illegible] test at [illegible]

Figure [illegible]. [illegible] test at Fort [illegible]

Before any noise exposure, each subject was instructed in the procedures for tracking an audiogram and given at least four practice audiograms. These were checked for consistency of tracking and threshold. They were not used in any of the data which follow.

On each exposure day, two audiograms were obtained on each volunteer before the noise exposure. These were averaged to provide his preexposure audiogram for that day. After each exposure, audiograms were obtained starting at 2, 20, and 60 minutes after the exposure (audiograms were to be obtained at longer postexposure time intervals if any TTS remained). The primary Threshold Shift (TS) data were calculated by subtracting the preexposure audiogram for that day from each of the postexposure audiograms.

Phase I

The first phase of this study was conducted at Redstone Arsenal, Alabama. The volunteers for phase I were eight General Dynamics employees* (seven males and one female). They were selected to have no hearing loss exceeding 10 dB at .5 and 1 kHz, 15 dB at 2 kHz and 20 dB at 3 kHz through 8 kHz (per CHABA, 1968). In addition, all volunteers were required to be clinically normal on screening spirometry, chest X-ray, and electroacoustic tympanometry.

Phase II

The second phase was conducted at Fort Benning, Georgia. The volunteers for phase II were 30 male military personnel with less than 5 years service. They all met the same selection criteria as the volunteers in phase I. Fifty-two volunteers were scheduled to complete phase II for a total of 60 volunteers for both phases. However, a malfunction of a VIPER round after 30 volunteers had completed phase II caused a premature termination of the test.

During the second phase, each volunteer received only one exposure condition: two rounds fired in rapid succession. Figure 4 shows a volunteer in firing position with safety personnel flanking him.

The hearing protection was the same as in phase I. In a few cases, the volunteers experienced difficulty inserting the earplugs and were assisted by the investigators.

During phase II, all exposures were monitored by measuring the noise on the opposite side of the weapon from the gunner's head (see Figure 5). Peak pressures and B-durations were determined in accordance with MIL-STD-1474A(MI).

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*General Dynamics was the prime contractor for development of the VIPER.

Results and discussion

A limited analysis of the data for the eight volunteers during phase I revealed no effect on hearing for the -10 dB, -5 dB or one round actual firing exposure conditions. As a result, the data for the two-round exposure from phase I were combined with the data from phase II (two rounds). Only these data are presented in what follows.

Table 1 contains a summary of the blast exposure data from phase II (phase I noise data were not measured by USAARL; however, the phase II data should be representative of the phase I exposures). These data are from channel 1, a position on the opposite side of the launch tube which corresponds to the gunner's ear position. Complete, round-by-round exposure data are in Appendix A. The average peak pressure, when analyzed using the trading rules for number of rounds and intensity implicit in MIL-STD-1474A(MI), would indicate four rounds per day should be allowed. However, this peak pressure is over the Z-curve and MIL-STD-1474(MI) prohibits exposures above the Z-curve. A worst case analysis, using the same military standard, would indicate only one round per day should be the limit.

Table 1

Summary of blast exposure data from phase II (Channel 1)

	Peak	B-Duration	ANR*
Mean	181.3 dB	16.7 ms	4
Maximum	185.5 dB	16.2 ms	1
Minimum	176.7 dB	17.9 ms	28

*Allowable number of rounds per trading rules of MIL-STD-1474A

The difference between the maximum and minimum peak levels (185.5 dB versus 176.7 for channel 1) indicates that the VIPER produces peak pressures which are highly variable. Generally, the durations are fairly consistent from round to round.

The threshold shift data were analyzed by examining the threshold shifts from the first postexposure audiograms for 2, 4, and 6 kHz. These are the frequencies where the maximum shifts would be expected. Figure 6 shows a histogram relating the number of individuals exhibiting various threshold shifts. The data were analyzed using 2 dB counting bins. These distributions are fairly symmetric and centered around 0 dB shift. A

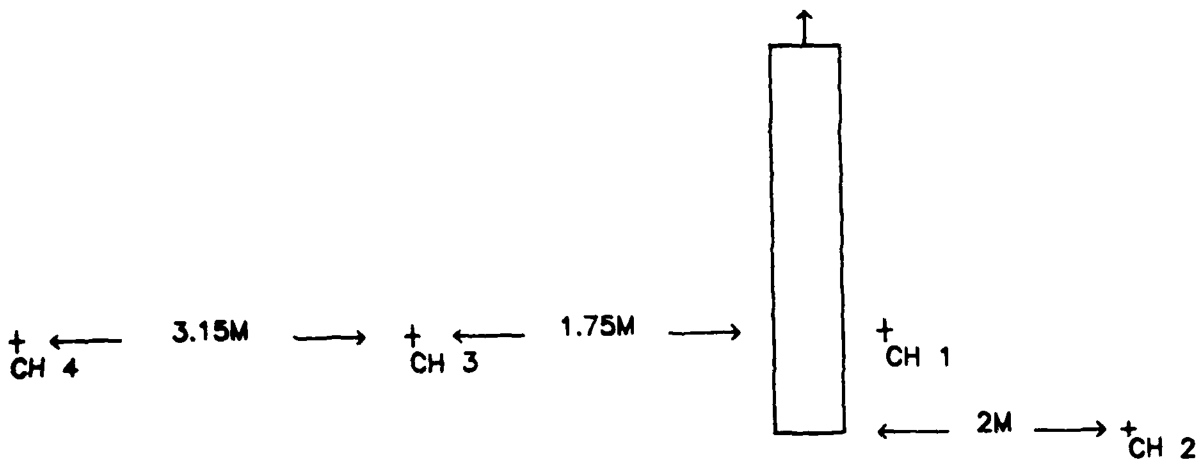

Figure 5. Schematic diagram showing gauge locations for the four measurement channels (CH1, CH2, CH3, CH4) during phase II.

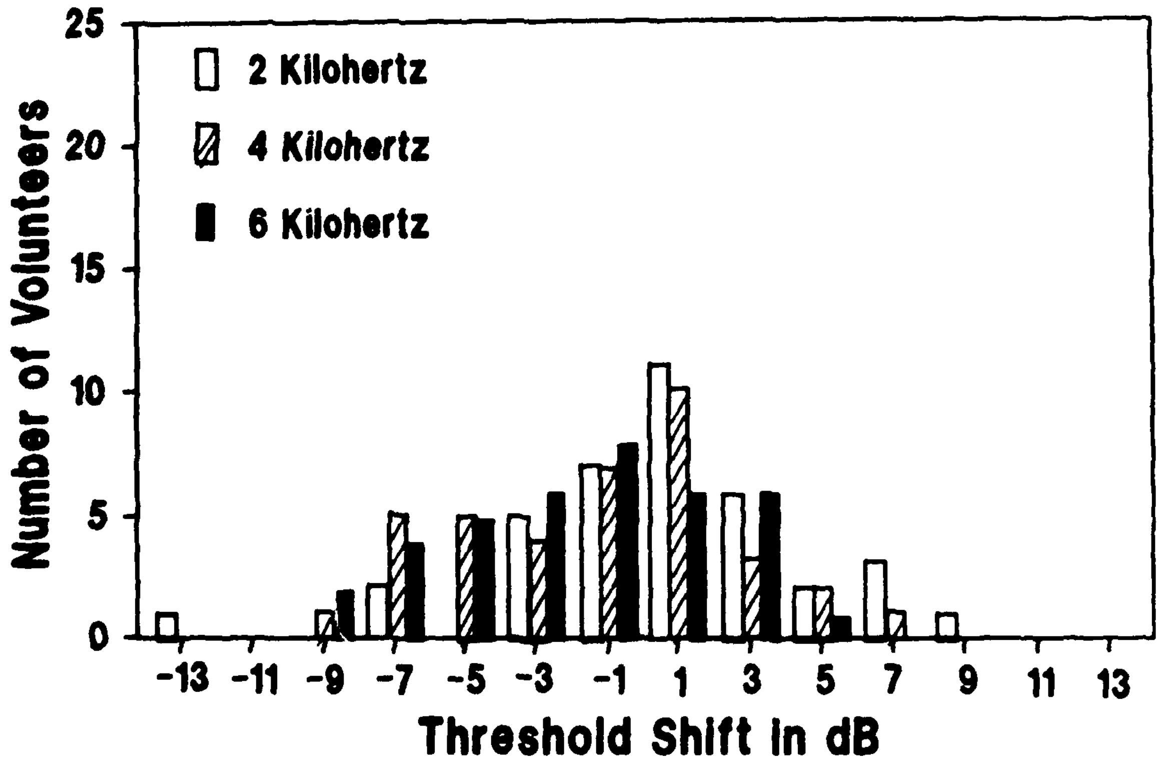

Figure 6. Histogram showing number of volunteers exhibiting various threshold shifts at three frequencies after firing two rounds of VIPER from the shoulder.

chi-square test for goodness of fit of these data to a normal distribution with zero mean and standard deviation estimated from the data was performed for each frequency. None of these tests indicated a significant departure from the normal distribution. In other words, the threshold shift data reflect normal audiometric measurement variability, rather than a consistent trend.

Using order statistics (Hogg and Craig, 1965, Patterson et al., 1985) with the sample size of 38, the largest measured threshold shift at each frequency represents an 86 percent confidence upper bound on the 95th percentile threshold shift. Figure 7 shows the average, estimated 95th percentile, and the 86 percent confidence upper bound on the 95th percentile compared to the "acceptable" threshold shift defined by CHABA (1968). Clearly, the average shift is near zero at all frequencies and the 95th percentile boundaries of the distribution are below the "acceptable" shifts defined by CHABA (1968). Examination of threshold shifts based on audiograms taken 20 minutes and 1 hour postexposure revealed no delayed threshold shifts.

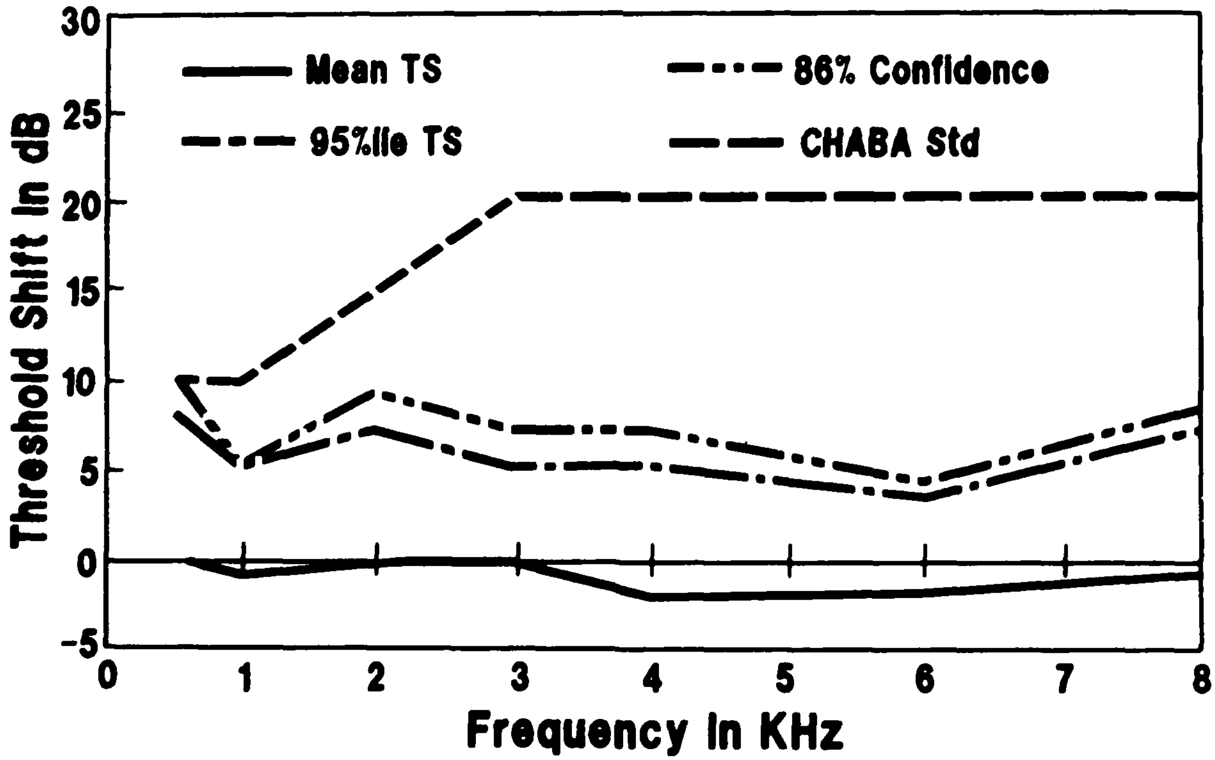

Figure 7. Results of the analysis of threshold shifts after firing two VIPER rounds as a function of audiometric test frequency.

Conclusion

Based on the results of this study, we conclude that properly used EAR earplugs provide adequate hearing protection for VIPER gunners for at least two rounds fired in rapid succession. If the hearing protectors are not properly and consistently used, they may not provide adequate protection. Other hearing protectors which do not provide equivalent attenuation may not be adequate either.

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Appendix A

Exposure data for 70 VIPER rounds

Values of peak pressure, B-duration (in milliseconds) and estimated allowable number of rounds (ANR) determined during manned firing of the VIPER

Shot Number	Parameter	Channel 1	Channel 2	Channel 3	Channel 4
1	PEAK				
	dB SPL	182.5	167.7	176.0	*MV
	kPa	26.7	4.9	12.6	MV
	psi	3.9	.7	1.8	MV
	B-DUR	15.0	16.8	15.7	MV
	ANR	2.5	1947.1	46.6	MV
2	PEAK				
	dB SPL	181.5	168.5	175.0	MV
	kPa	23.8	5.3	11.2	MV
	psi	3.4	.7	1.6	MV
	B-DUR	15.6	17.3	16.2	MV
	ANR	3.7	1295.5	70.9	MV
3	PEAK				
	dB SPL	177.9	174.0	175.0	171.2
	kPa	15.3	10.0	11.2	7.3
	psi	2.3	1.5	1.6	1.1
	B-DUR	19.3	16.2	15.4	16.3
	ANR	14.8	112.3	75.8	404.4
4	PEAK				
	dB SPL	182.0	174.8	176.4	171.7
	kPa	25.2	11.0	13.2	7.7
	psi	3.7	1.6	1.9	1.1
	B-DUR	15.5	16.3	15.0	16.9
	ANR	3.0	77.1	41.2	306.2
5	PEAK				
	dB SPL	181.5	175.7	177.1	173.1
	kPa	23.8	12.2	14.3	9.0
	psi	3.4	1.8	2.1	1.3
	B-DUR	17.3	16.6	13.9	13.8
	ANR	3.2	49.7	33.0	210.3
6	PEAK				
	dB SPL	181.5	175.8	175.8	172.2
	kPa	23.8	12.3	12.3	8.1
	psi	3.4	1.8	1.8	1.2
	B-DUR	15.6	16.2	15.7	14.9
	ANR	3.7	49.0	51.1	287.5
7	PEAK				
	dB SPL	180.9	173.5	175.1	171.6
	kPa	22.2	9.5	11.4	7.6
	psi	3.2	1.4	1.7	1.1
	B-DUR	MV	MV	15.3	17.1
	ANR	MV	MV	73.0	315.6
8	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-DUR	MV	MV	MV	MV
	ANR	MV	MV	MV	MV

*MV denotes missing value

Values of peak pressure, B-duration, ANRs for VIPER (continued)

Shot Number	Parameter	Channel 1	Channel 2	Channel 3	Channel 4
9	PEAK				
	dB SPL	176.7	175.6	174.9	173.4
	kPa	13.7	12.1	11.1	9.4
	psi	2.0	1.7	1.6	1.4
	B-DUR	17.9	16.2	15.3	15.5
	ANR	28.4	53.7	80.0	157.0
10	PEAK				
	dB SPL	176.9	176.0	177.8	173.4
	kPa	14.0	12.6	15.5	9.4
	psi	2.0	1.8	2.3	1.4
	B-DUR	19.3	15.7	15.6	15.2
	ANR	23.4	46.6	20.5	161.1
11	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-DUR	MV	MV	MV	MV
	ANR	MV	MV	MV	MV
12	PEAK				
	dB SPL	179.9	175.9	175.9	171.8
	kPA	19.8	12.5	12.5	7.8
	psi	2.9	1.8	1.8	1.1
	B-DUR	17.2	15.4	15.7	22.3
	ANR	6.9	50.1	48.8	202.2
13	PEAK				
	dB SPL	182.9	175.6	177.1	172.6
	kPa	27.9	12.1	14.3	8.5
	psi	4.1	1.7	2.1	1.2
	B-Dur	MV	15.8	MV	17.0
	ANR	MV	55.6	MV	200.7
14	PEAK				
	dB SPL	179.6	175.0	176.2	172.5
	kPa	19.1	11.2	12.9	8.4
	psi	2.8	1.6	1.9	1.2
	B-Dur	18.2	15.5	15.0	14.9
	ANR	7.3	75.1	45.2	250.4
15	PEAK				
	dB SPL	180.9	173.4	175.2	171.6
	kPa	22.2	9.4	11.5	7.6
	psi	3.2	1.4	1.7	1.1
	B-Dur	17.1	16.5	16.5	14.4
	ANR	4.4	144.5	63.1	396.6
16	PEAK				
	dB SPL	177.3	176.1	175.4	171.4
	kPa	14.7	12.8	11.8	7.4
	psi	2.1	1.9	1.7	1.1
	B-Dur	17.9	15.3	16.1	16.2
	ANR	21.5	46.1	59.4	371.9
17	PEAK				
	dB SPL	180.3	173.5	176.3	171.8
	kPa	20.7	9.5	13.1	7.8
	psi	3.0	1.4	1.9	1.1
	B-DUR	15.9	15.9	15.6	16.5
	ANR	6.3	144.9	40.9	301.8

Values of peak pressure, B-duration, ANRs for VIPER (continued)

Shot Number	Parameter	Channel 1	Channel 2	Channel 3	Channel 4
18	PEAK				
	dB SPL	183.3	174.2	176.8	170.6
	kPa	29.2	10.3	13.8	6.8
	psi	4.2	1.5	2.0	1.0
	B-DUR	15.6	16.7	15.3	20.3
	ANR	1.6	98.4	33.4	398.3
19	PEAK				
	dB SPL	182.4	175.8	178.9	171.7
	kPa	26.4	12.3	17.6	7.7
	psi	3.8	1.8	2.6	1.1
	B-Dur	17.2	16.5	15.2	16.8
	ANR	2.2	47.8	12.8	308.6
20	PEAK				
	dB SPL	183.2	176.5	178.0	170.1
	kPa	28.9	13.4	15.9	6.4
	psi	4.2	1.9	2.3	.9
	B-Dur	17.0	15.5	15.4	15.9
	ANR	1.5	37.7	19.0	693.7
21	PEAK				
	dB SPL	182.8	174.3	177.8	171.4
	kPa	27.6	10.4	15.5	7.4
	psi	4.0	1.5	2.3	1.1
	B-Dur	16.2	17.3	15.9	14.8
	ANR	2.0	89.6	20.0	419.3
22	PEAK				
	dB SPL	180.1	175.2	177.8	169.8
	kPa	20.2	11.5	15.5	6.2
	psi	1.6	1.7	2.3	.9
	B-Dur	16.0	16.2	14.4	17.0
	ANR	6.9	64.6	22.8	728.7
23	PEAK				
	dB SPL	179.7	176.4	177.9	170.2
	kPa	19.3	13.2	15.7	6.5
	psi	2.8	1.9	2.3	.9
	B-Dur	17.4	15.7	15.0	13.8
	ANR	7.4	38.8	20.6	799.7
24	PEAK				
	dB SPL	182.7	176.3	176.7	168.2
	kPa	27.3	13.1	13.7	5.1
	psi	4.0	1.9	2.0	.7
	B-Dur	15.8	16.4	15.2	16.1
	ANR	2.1	38.3	35.2	1636.6
25	PEAK				
	dB SPL	180.7	176.6	177.7	169.4
	kPa	21.7	13.5	15.3	5.9
	psi	3.1	2.0	2.2	.9
	B-Dur	17.3	15.3	14.8	16.3
	ANR	4.7	36.6	23.0	926.5
26	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-Dur	MV	MV	MV	MV
	ANR	MV	MV	MV	MV

Values of peak pressure, B-duration, ANRs for VIPER (continued)

Shot Number	Parameter	Channel 1	Channel 2	Channel 3	Channel 4
27	PEAK				
	dB SPL	182.3	176.2	176.7	169.9
	kPa	26.1	12.9	13.7	6.3
	psi	3.8	1.9	2.0	.9
	B-Dur	15.3	15.8	13.7	15.8
	ANR	2.7	42.2	40.5	767.0
28	PEAK				
	dB SPL	178.0	174.9	176.8	171.8
	kPa	15.9	11.1	13.8	7.8
	psi	2.3	1.6	2.0	1.1
	B-Dur	18.7	16.0	15.7	16.0
	ANR	14.7	75.4	32.2	314.4
29	PEAK				
	dB SPL	180.6	175.4	176.7	173.8
	kPa	21.4	11.8	13.7	9.8
	psi	3.1	1.7	2.0	1.4
	B-Dur	16.1	17.3	15.8	13.9
	ANR	5.4	54.0	33.5	150.9
30	PEAK				
	dB SPL	179.1	176.0	176.4	169.8
	kPa	18.0	12.6	13.2	6.2
	psi	2.6	1.8	1.9	.9
	B-Dur	18.4	16.1	15.7	16.5
	ANR	9.1	45.1	38.8	758.2
31	PEAK				
	dB SPL	182.5	176.4	175.8	170.1
	kPa	26.7	13.2	12.3	6.4
	psi	3.9	1.9	1.8	.9
	B-Dur	8.3	14.3	15.6	15.4
	ANR	5.4	43.9	51.5	723.8
32	PEAK				
	dB SPL	179.4	176.7	176.9	169.9
	kPa	18.7	13.7	14.0	6.3
	psi	2.7	2.0	2.0	.9
	B-Dur	18.7	15.5	15.3	14.5
	ANR	7.7	34.3	31.9	859.7
33	PEAK				
	dB SPL	180.3	178.5	176.2	171.0
	kPa	20.7	16.8	12.9	7.1
	psi	3.0	2.4	1.9	1.0
	B-Dur	15.7	16.2	14.8	15.2
	ANR	6.4	14.1	46.0	486.6
34	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-Dur	MV	MV	MV	MV
	ANR	MV	MV	MV	MV
35	PEAK				
	dB SPL	181.0	175.9	177.8	171.0
	kPa	22.4	12.5	15.5	7.1
	psi	3.3	1.8	2.3	1.0
	B-Dur	MV	MV	MV	16.4
	ANR	MV	MV	MV	439.8

Values of peak pressure, B-duration, ANRs for VIPER (continued)

Shot Number	Parameter	Channel 1	Channel 2	Channel 3	Channel 4
36	PEAK				
	dB SPL	180.3	175.9	178.0	169.6
	kPa	20.7	12.5	15.9	6.0
	psi	3.0	1.8	2.3	.9
	B-Dur	15.6	16.2	17.9	13.7
	ANR	6.5	46.8	15.6	1064.4
37	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-Dur	MV	MV	MV	MV
	ANR	MV	MV	MV	MV
38	PEAK				
	dB SPL	181.7	174.2	175.9	171.7
	kPa	24.3	10.3	12.5	7.7
	psi	3.5	1.5	1.8	1.1
	B-Dur	17.7	17.4	15.5	15.1
	ANR	2.9	93.1	49.6	355.6
39	PEAK				
	dB SPL	185.5	176.6	176.5	170.8
	kPa	37.7	13.5	13.4	6.9
	psi	5.5	2.0	1.9	1.0
	B-Dur	16.2	15.7	15.6	18.7
	ANR	.6	35.4	37.3	405.1
40	PEAK				
	dB SPL	181.7	174.6	177.4	170.4
	kPa	24.3	10.7	14.8	6.6
	psi	3.5	1.6	2.2	1.0
	B-Dur	MV	MV	MV	19.1
	ANR	MV	MV	MV	473.5
41	PEAK				
	dB SPL	178.0	176.5	177.8	170.6
	kPa	15.9	13.4	15.5	6.8
	psi	2.3	1.9	2.3	1.0
	B-Dur	MV	MV	MV	16.4
	ANR	MV	MV	MV	528.8
42	PEAK				
	dB SPL	179.4	176.1	176.2	169.5
	kPa	18.7	12.8	12.9	6.0
	psi	2.7	1.9	1.9	.9
	B-Dur	18.1	15.1	13.8	28.1
	ANR	8.1	46.9	50.5	429.1
43	PEAK				
	dB SPL	179.4	177.6	177.2	170.5
	kPa	18.7	15.2	14.5	6.7
	psi	2.7	2.2	2.1	1.0
	B-Dur	MV	MV	MV	13.9
	ANR	MV	MV	MV	689.8
44	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-Dur	MV	MV	MV	MV
	ANR	MV	MV	MV	MV

Values of peak pressure, B-duration, ANRs for VIPER (continued).

Shot Number	Parameter	Channel 1	Channel 2	Channel 3	Channel 4
45	PEAK				
	dB SPL	181.3	175.2	176.0	170.3
	kPa	23.2	11.5	12.6	6.5
	psi	3.3	1.7	1.8	.9
	B-Dur	16.3	18.8	15.9	14.1
	ANR	3.9	53.0	45.8	742.2
46	PEAK				
	dB SPL	182.7	175.8	180.0	169.4
	kPa	27.3	12.3	20.0	5.9
	psi	4.0	1.8	2.9	.9
	B-Dur	15.8	15.7	13.2	18.1
	ANR	2.1	51.1	9.3	806.1
47	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-Dur	MV	MV	MV	MV
	ANR	MV	MV	MV	MV
48	PEAK				
	dB SPL	179.2	178.0	175.2	170.8
	kPa	18.2	15.9	11.5	6.9
	psi	2.6	2.3	1.7	1.0
	B-Dur	17.4	15.6	26.4	16.5
	ANR	9.3	18.7	33.8	478.4
49	PEAK				
	dB SPL	181.1	177.9	176.5	171.5
	kPa	22.7	15.7	13.4	7.5
	psi	3.3	2.3	1.9	1.1
	B-Dur	16.9	16.3	14.7	16.6
	ANR	4.0	18.5	40.4	343.8
50	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-Dur	MV	MV	MV	MV
	ANR	MV	MV	MV	MV
51	PEAK				
	dB SPL	181.6	177.2	175.9	170.5
	kPa	24.0	14.5	12.5	6.7
	psi	3.5	2.1	1.8	1.0
	B-Dur	17.3	15.1	15.6	14.5
	ANR	3.1	28.2	49.2	652.2
52	PEAK				
	dB SPL	177.7	175.2	177.4	171.7
	kPa	15.3	11.5	14.8	7.7
	psi	2.2	1.7	2.2	1.1
	B-Dur	17.2	17.4	16.0	14.6
	ANR	18.9	58.8	23.9	371.9
53	PEAK				
	dB SPL	183.3	175.3	176.7	171.4
	kPa	29.2	11.6	13.7	7.4
	psi	4.2	1.7	2.0	1.1
	B-Dur	15.0	15.0	15.8	14.8
	ANR	1.7	68.4	33.5	419.3

Values of peak pressure, B-duration, ANRs for VIPER (continued)

Shot Number	Parameter	Channel 1	Channel 2	Channel 3	Channel 4
54	PEAK				
	dB SPL	181.5	176.8	177.5	171.4
	kPa	23.8	13.8	15.0	7.4
	psi	3.4	2.0	2.2	1.1
	B-Dur	16.9	14.6	14.7	16.3
	ANR	3.4	35.5	25.5	368.8
55	PEAK				
	dB SPL	179.6	176.2	178.1	170.7
	kPa	19.1	12.9	16.1	6.9
	psi	2.7	1.9	2.3	1.0
	B-Dur	16.2	16.5	13.9	18.3
	ANR	8.5	39.8	20.8	436.5
56	PEAK				
	dB SPL	181.4	177.9	177.5	171.7
	dB SPL	23.5	15.7	15.0	7.7
	psi	3.4	2.3	2.2	1.1
	B-Dur	17.9	14.8	15.2	17.7
	ANR	3.3	21.0	24.4	287.9
57	PEAK				
	dB SPL	182.1	175.8	177.2	169.1
	kPa	25.5	12.3	14.5	5.7
	psi	3.7	1.8	2.1	.8
	B-Dur	17.0	15.5	14.9	16.6
	ANR	2.5	52.0	28.8	1038.2
58	PEAK				
	dB SPL	182.3	176.7	176.3	170.6
	kPa	26.1	13.7	13.1	6.8
	psi	3.8	2.0	1.9	1.0
	B-Dur	16.5	15.7	15.3	14.2
	ANR	2.4	33.8	42.0	640.3
59	PEAK				
	dB SPL	MV	MV	MV	MV
	kPa	MV	MV	MV	MV
	psi	MV	MV	MV	MV
	B-Dur	MV	MV	MV	MV
	ANR	MV	MV	MV	MV
60	PEAK				
	dB SPL	179.9	176.4	176.7	170.5
	kPa	19.8	13.2	13.7	6.7
	psi	2.9	1.9	2.0	1.0
	B-Dur	16.6	15.6	15.5	16.5
	ANR	7.2	39.1	34.3	549.3
61	PEAK				
	dB SPL	180.3	179.4	176.6	169.5
	kPa	20.7	18.7	13.5	6.0
	psi	3.0	2.7	2.0	.9
	B-Dur	16.4	14.9	16.0	16.5
	ANR	6.1	10.4	34.5	870.5
62	PEAK				
	dB SPL	180.8	177.9	178.5	172.4
	kPa	21.9	15.7	16.8	8.3
	psi	3.2	2.3	2.4	1.2
	B-Dur	17.1	16.1	14.7	12.8
	ANR	4.6	18.8	16.1	320.9

Values of peak pressure, B-duration, ANRs for VIPER (continued)

Shot Number	Parameter	Channel 1	Channel 2	Channel 3	Channel 4
63	PEAK				
	dB SPL	181.5	176.5	176.6	173.4
	kPa	23.8	13.4	13.5	9.4
	psi	3.4	1.9	2.0	1.4
	B-Dur	16.7	15.0	14.6	15.3
	ANR	3.4	39.3	38.9	159.7
64	PEAK				
	dB SPL	181.5	176.8	177.1	170.5
	kPa	23.8	13.8	14.3	6.7
	psi	3.4	2.0	2.1	1.0
	B-Dur	17.1	15.6	15.0	18.2
	ANR	3.3	32.5	29.8	482.2
65	PEAK				
	dB SPL	180.9	175.5	177.3	171.9
	kPa	22.2	11.9	14.7	7.9
	psi	3.2	1.7	2.1	1.1
	B-Dur	16.2	16.4	15.1	14.6
	ANR	4.7	55.4	27.0	339.1
66	PEAK				
	dB SPL	183.3	177.5	176.7	171.1
	kPa	29.2	15.0	13.7	7.2
	psi	4.2	2.2	2.0	1.0
	B-Dur	15.7	15.5	15.2	17.3
	ANR	1.6	23.8	35.2	391.3
67	PEAK				
	dB SPL	182.4	175.3	176.4	171.5
	kPa	26.4	11.6	13.2	7.5
	psi	3.8	1.7	1.9	1.1
	B-Dur	14.9	16.0	16.0	16.5
	ANR	2.6	62.7	37.8	346.6
68	PEAK				
	dB SPL	181.8	176.1	178.1	173.6
	kPa	24.6	12.8	16.1	9.6
	psi	3.6	1.9	2.3	1.4
	B-Dur	MV	MV	MV	14.9
	ANR	MV	MV	MV	150.9
69	PEAK				
	dB SPL	180.0	172.6	175.5	171.5
	kPa	20.0	8.5	11.9	7.5
	psi	2.9	1.2	1.7	1.1
	B-Dur	18.9	17.7	16.5	20.2
	ANR	5.8	190.2	54.9	264.9
70	PEAK				
	dB SPL	179.0	174.5	177.1	173.7
	kPa	17.8	10.6	14.3	9.7
	psi	2.6	1.5	2.1	1.4
	B-Dur	18.0	16.4	15.3	15.1
	ANR	9.8	87.8	29.1	141.6

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